Kosterlitz-Thouless Transition in Thin Films of ^{4}He in the Presence of Disorder

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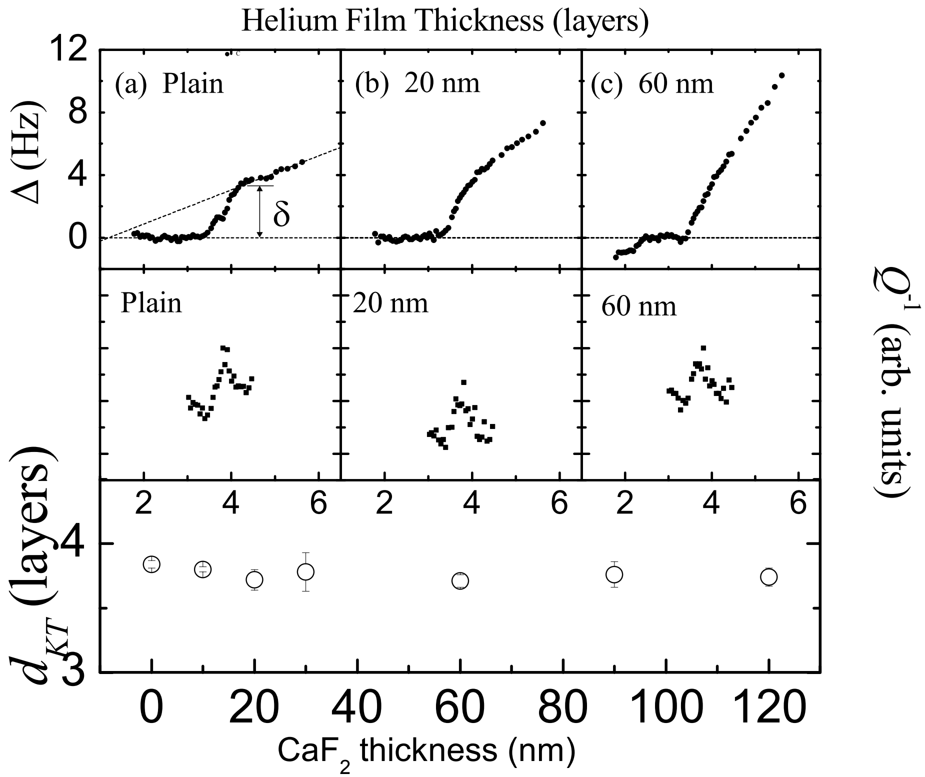
The Kosterlitz-Thouless transition is a phase transition that can be seen in pure ^{4}He films on smooth surfaces by the technique of quartz crystal microbalance. In this technique mass decouples from the substrate at the superfluid transition and this is seen as a shift in the resonance frequency of the microbalance. For a smooth surface the size of the frequency shift is observed to be as predicted by the theory of Kostelitz and Nelson. But, it has not been known how this behavior evolves as the roughness of the surface is increased. Our recent work shows that roughness introduces substantial changes in the behavior as disorder increases.



Behavior of the frequency shift (top row) as a function of helium film thickness for three thicknesses of CaF_2 that is deposited on surfaces to make them rough. The middle panels show the dissipation. The helium film thickness at which the Kosterlitz-Thouless transition takes place does not change, as shown in the lower panel.

D.R. Luhman and R.B. Hallock,
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Education:
This work began with the work of graduate student Justin Herrmann, who studied the behavior of third sound (waves on helium films) in the presence of *strong* surface disorder. He also used quartz crystal microbalances but observed no frequency shift signature at the Kosterlitz-Thouless transition. Justin is now employed in instrumentation. A new graduate student Dwight Luhman is working on the influence of surface disorder on the Kosterlitz-Thouless transition as a function of gradually increasing well-characterized disorder. He is assisted by an undergraduate physics major, Kyle Thompson.

Societal Impact:
The natural world is not a perfect place. So, it is important to see how our basic understanding of fundamental phenomena, such as the Kosterlitz-Thouless transition for a pure system, evolves in the presence of increasing amounts of well-characterized disorder. Such observations should allow emerging theory to be tested and such theory should have application in a variety of real-world situations.

Phase transitions, such as ice melting to form water or water boiling to make steam, are very common in nature. And understanding these in very pure systems has led us to an understanding of the fundamental nature of such transitions. In turn, this understanding has led to great improvements in various industrial processes that involve phase transitions that benefit society. But, the real world is filled with disorder and perturbations of various sorts that make the behavior of phase transitions more complicated. In the work described here, we have studied a particular phase transition in thin films of liquid helium. For a smooth surface, the observations are in agreement with theory. But, there is no theory for what will happen to this phase transition when the helium is on a rough (disordered) surface. So, we have carried out experiments that discovered that the phase transition becomes somewhat smeared out in some of its aspects, but not in others. It is likely that theory will now be developed to help to explain and understand why this is the case. Thus we are likely to be led to a better understanding of phase transitions in disordered systems generally and this will likely have significance well beyond the specific system studied here.